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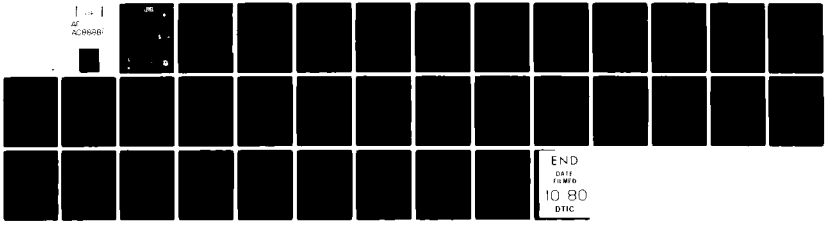

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Automation of Visual Weather Observations

H. ALBERT BROWN

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METEOROLOGY DIVISION PROJECT 6670
AIR FORCE GEOPHYSICS LABORATORY
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AIR FORCE SYSTEMS COMMAND, USAF

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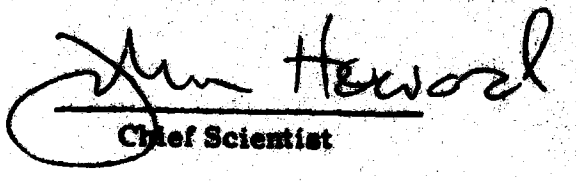

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A study was performed to determine the feasibility of objectively and automatically determining two key components of an aviation weather observation; present weather and obstruction to vision. The automated system utilized was an instrumented tower and surface array of sensors located at the AFGL Weather Test Facility (WTF), Otis AFB, Massachusetts. The objective method consisted of a decision tree program (AUTO) based on several uniquely different responses by these weather sensors to the same weather phenomena and on discrimination techniques using tower and surface instrument comparison.

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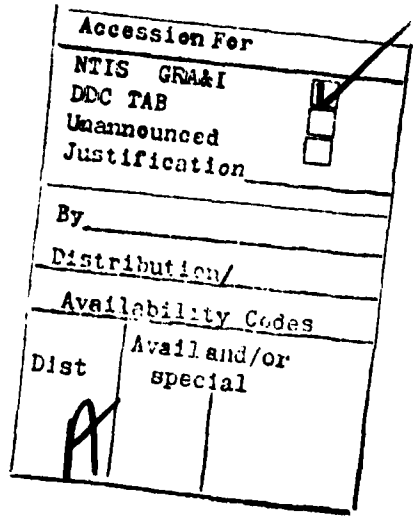
The ability of AUTO to monitor rapidly changing weather events and to discriminate different types of weather is demonstrated through selected hourly periods of observations taken at 1-min intervals.

Hourly observations generated over a 14-month period, March 1978 through April 1979, are compared with FAA observations to determine the effectiveness of AUTO. Major areas of agreement were found in the discrimination of fog, haze, snow, rain, and no weather. Final results show that the FAA observations of the existence and non-existence of obstructions to vision and present weather were duplicated in 82 and 86% of the cases. Thus the acquisition of real weather for an aviation weather observation, a duty presently performed by a human observer, is obtainable through an objective decision-tree program using an automated sensor array.

Preface

The systems programming carried out by Mrs. Mary Hermann in the Regis College contract and Mrs. Joan Ward in the Systems and Applied Sciences Corporation contract is gratefully acknowledged. Many individuals from the Air Force Geophysics Laboratory assisted in this program; in particular, Mr. Leo Jacobs and Mr. Ralph Hoar extended excellent cooperation and field support in the operation of the AFGL Weather Test Facility at Otis AFB, Massachusetts. In addition, the author is grateful to Dr. Stuart Muench and Mr. Donald Chisholm for valuable discussions concerning the program and to Mr. Chisholm for many helpful comments on the paper. The author also wishes to acknowledge the assistance of Miss Karen Sullivan in typing the manuscript.



Contents

1. INTRODUCTION 7

2. INSTRUMENTATION 9

   2.1 AFGL Weather Test Facility 9
   2.2 Weather Sensors 10

3. AUTOMATED DECISION-TREE PROGRAM 11

   3.1 Obstructions to Vision Program 12
   3.2 Present Weather Program 14

4. OBSERVATIONS 14

5. COMPARATIVE ANALYSIS OF OBSERVATIONS 23

   5.1 Obstructions to Vision Verification 24
   5.2 Present Weather Verification 28

6. SUMMARY AND CONCLUSIONS 31

REFERENCES 33

Illustrations

1. Configuration of Instrumented Towers and Ground Site at AFGL Weather Test Facility, Otis AFB 10

2. Flow Charts of Obstruction to Vision and Present Weather Determination Program 13

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Illustrations

3. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0900 GMT, 8 June 1978 17

4. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0200 GMT, 15 August 1978 18

5. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0300 GMT, 15 August 1978 19

6. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0600 GMT, 4 November 1978 20

7. Example of One Hour of Automated Decision-Tree Program Output Beginning at 2300 GMT, 7 February 1979 21

8. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0100 GMT, 18 January 1979 22

9. Verification of Fourteen Months (March 1978 through April 1979) of Obstruction to Vision Observations Generated by the Automated Decision-Tree Program With FAA Weather Observations 24

10. Simplification of Figure 9 Through Categorization 26

11. Verification of Fourteen Months (March 1978 through April 1979) of Present Weather Observations Generated by the Automated Decision-Tree Program (AUTO) With FAA Weather Observations 28

12. Simplification of Figure 11 Through Categorization 30

Tables

1. Symbols for Weather, Obstruction to Vision and Precipitation Intensity 11

Automation of Visual Weather Observations

1. INTRODUCTION

The need for automatic surface meteorological observing systems has been well established for many years.[1] Acquisition of data from remote locations,[2,3] relieving the human observer of the necessity of constantly monitoring rapidly changing weather events,[4] and the ability to perform numerous routine operations continuously[5] are but a few of the reasons.

In response to Air Force requirements, a project was begun in January 1976 to develop a low-cost, fully-automated system, modular in design, which would also be simple to maintain. One phase of the project was the installation of a prototype Modular Automated Weather System (MAWS) at Scott AFB, Illinois to demonstrate the versatility of the system. Briefly summarized, weather instruments at three runway sites and a tower were polled several times each minute, voltages were converted to meteorological values and transmitted and displayed at four locations on the base. Variables observed included wind, temperature, dewpoint, visibility, pressure, and cloud-base height. In addition, short range forecasts of visibility and cloud-base height were generated and several critical weather criteria, for example, wind chill temperatures and runway cross winds, were monitored.[6,7]

(Received for publication 27 March 1980.)

(Due to the large number of references cited above, they will not be listed here. See References, page 33.)

The variables measured in MAWS almost constitute a a complete aviation weather observation. However, the prevailing visibility reported was derived from a single sensor, which is only an approximation to the prevailing visibility that the human observer is required to take. The cloud-base height was also a substitute for the ceiling observation that is required, and sky conditions were not observed at all. The final items missing from the MAWS automated weather observation were the weather and obstructions to vision.

The weather and obstructions to vision elements are those atmospheric phenomena which are classified as hydrometeors and lithometeors, that is, liquid or solid water particles and mostly solid dry particles suspended or falling through the atmosphere. Since the inception of weather observations, human observers have been required to determine these elements visually.

Several methods, utilizing different instruments and techniques, are currently under consideration for the automation of the two preceding elements. Moroz[8] noted that the rotating-beam and the lidar ceilometer provide distinctive returns during rain, snow, and fog.

Interest has also been evidenced recently in the possibility of identifying several classes of weather through the observation of scintillation and forward scatter of a laser beam. Recent publications[9, 10] described the efforts to differentiate clear air, rain, snow, fog, and drizzle with a prototype laser instrument. Preliminary observations led to the suggestion that such a technique is feasible, however, its reliability still awaits assessment.

An alternative approach considered by the AFGL was to use the automated array of weather sensors composing MAWS, augmented with a few specialized sensors, operating in conjunction with a weather-selective decision-tree computer program.

This approach was felt to have merit because of the experience and empirical evidence gained on instrumental response to weather phenomena during the operation of the AFGL Mesonetwork[11] between 1972 and 1976 and because of independent

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8. Moroz, Eugene, Y. (1977) Investigations of Sensors and Techniques to Automate Weather Observations, AFGL-TR-77-0041, AD A040747.

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10. Sanders, M. J., Jr. (1979) A Laser weather identifier system, Proc. of the 8th Technical Exchange Conference, 28 Nov - 1 Dec 1978, Air Weather Service TR-79-001:79-86.

11. Hering, W. S., Brown, H. A., and Muench, H. A. (1972) Mesoscale forecasting experiments, Bull. Am. Meteorol. Soc. 53(No. 12):1180-1183.

studies[12, 13] which documented the response characteristics of some of the sensors to different weather types. A preliminary report[14] described the instrumentation, the relationships of sensors to weather type, the decision-tree program, and demonstrated the feasibility of the concept. The present report documents the details of a 14-month test of the automated weather system and presents the results of their comparison with human observations.

2. INSTRUMENTATION

2.1 AFGL Weather Test Facility

For several years, AFGL has operated a Weather Test Facility (WTF) at Otis AFB, Massachusetts. The WTF was designed to serve as a base for evaluating new sensors under consideration for inclusion in the AWS inventory,[8] for collecting data to be used in weather forecasting techniques development, and for testing and improving weather automation methods.[15]

The general configuration of the WTF is shown in Figure 1. The facility consists of three instrumented towers, A, B, and C, arranged to measure weather variables to heights of 60 m, 30 m, and 3 m along an imaginary aircraft glideslope. Two instrumented towers, P and Q, are located 500 m on each side of the simulated approach zone and have served as primary data points in studies determining weather event probabilities along the approach zone with offset tower measurements.[15] In addition a group of state-of-the-art and operational visibility, wind, and precipitation sensors are located at Site X.

Since the purpose of this research was to incorporate an automatic determination of weather into the MAWS, the decision was made to select a basic MAWS complement of instruments present in the WTF and duplicate, as nearly as possible, the MAWS itself. Thus, data were collected and analyzed only from Tower A and the complex of surface instruments at Site X. The wind, temperature, dew point, and visibility instruments at A and X fulfilled the basic MAWS instruments requirements.

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12. Chisholm, D., and Jacobs, L. P. (1975) An Evaluation of Scattering Type Visibility Instruments, AFGL-TR-75-0411, AD B010224L.
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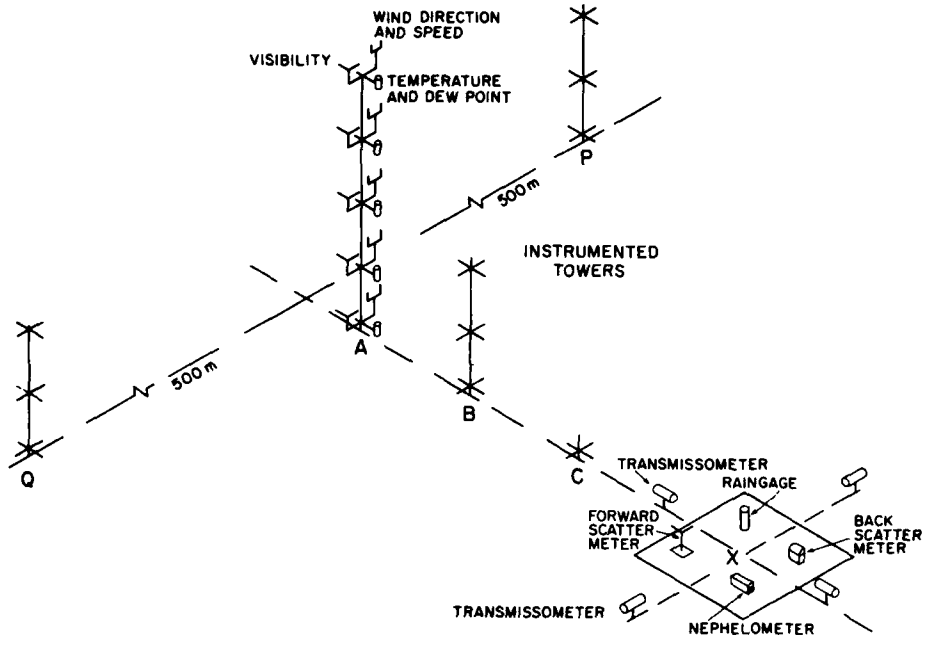

Figure 1. Configuration of Instrumented Towers and Ground Site at AFGL Weather Test Facility, Otis AFB

2.2 Weather Sensors

Before preceding to a discussion of the decision-tree program, the observations it produces and their verification, a brief summary of the weather sensors used in this study will be given. A more detailed description of the automated sensors can be found in a previous study.[14]

Visibility measurements were made with four types of instruments: the EG&G Model 207 Forward Scatter Meter (FSM), the transmissometer (TRANS), the Impulsphysics Back Scatter Meter (VIDF), and the MRI Model 1550 Integrating Nephelometer (NEPH). Wind directions and speeds were obtained from Climatronics Wind Mark I wind sets. Temperatures and dew points were measured with EG&G Model 110S-M sensors, and precipitation was recorded with a Belfort Model 5-405 tipping-bucket rain gage.

3. AUTOMATED DECISION-TREE PROGRAM

The contents of an aviation weather observation are based on agreements between the World Meteorological Organization, international and domestic aviation interests, and civil and military weather services. Table 1 lists the current elements available to observers to categorize weather occurring at a given time. Much discussion could be generated relative to the merits or necessity of many of the elements in this table. Obviously some are more important than others for aviation purposes. The principal effort in this study was to automatically determine as many of these elements as possible. Consideration of the instrument array available at the Otis WTF led to the selection of the elements, denoted in Table 1, for testing in the system.

Table 1. Symbols for Weather, Obstructions to Vision and Precipitation Intensity. Closed circles opposite symbols denote inclusion in the Automated Decision-Tree Program, (from Federal Meteorological Handbook No. 1, see Reference 18).

		Weather Symbols			
	T	Thunderstorm	O	RW	Rain Showers
	T+	Severe Thunderstorm	●	S	Snow
	A	Hail		SG	Snow Grains
	IC	Ice Crystals		SP	Snow Pellets
	IP(W)	Ice Pellets (Showers)	O	SW	Snow Showers
●	L	Drizzle	●	ZL	Freezing Drizzle
●	R	Rain	●	ZR	Freezing Rain
		Obstructions to Vision			
	BD	Blowing Dust	●	H	Haze
●	BN	Blowing Sand		D	Dust
●	BS	Blowing Snow	●	F	Fog
	BY	Blowing Spray	●	GF	Ground Fog
●	K	Smoke	●	IF	Ice Fog
		Precipitation Intensity Symbols			
	--	Very light	●		Absence of symbol indicates moderate except for A and IC
●	—	Light			
●	'	Heavy			

Rain and snow showers are denoted as partially included because the program generates an observation each minute. Thus showery conditions can be deduced by noting rapid variations in precipitation intensity.

The major elements missing in the AFGL automated weather decision-tree program are thunderstorms (T, T+), and hail (A). Several attempts to detect thunderstorms were discussed in a previous paper[16] using techniques other than radar. In addition, instruments have been designed[17] which appear capable of automatically measuring the momentum impacted to a sensing device by a hailstone strike.

3.1 Obstructions to Vision Program

The obstructions to vision (OV) section of the decision-tree program was designed to be initiated whenever the visibility, as measured by an FSM, decreased to less than seven miles (denoted by an extinction coefficient of 3×10^{-4} m^{-1}). A simplified flow diagram, upper diagram in Figure 2, illustrates the branches available in the decision tree for detecting the appropriate OV element.

Following an initial visibility reading which is less than seven miles, editing routines in the program determine whether the observation is valid. These checks consist of comparisons with other FSM's on the tower or at site X. The tendency of the FSM occasionally to detect scattering from non-visibility reducing sources is thus taken into account.

Given that the observation is valid, a test of the temperature-dew point difference determines whether the "wet" or "dry" branch of the tree will be followed. Fog of some type will be reported if the temperature-dew point difference is less than 6°C. If the difference is equal to or greater than 6°C, then the program branches and tests are made for wind gusts, nephelometer values, and vertical profiles of extinction coefficient (EXCO) in order to differentiate haze, or blowing sand and dust, and, in some cases, blowing snow.

If the temperature-dew point difference is less than 6°C, then the program is directed to an examination of the vertical gradient of EXCO. If the EXCO at the uppermost level of the tower is significantly less (60%) than at the lowest level, then ground fog (GF) is chosen as the obstruction. If, however, the upper level EXCO is similar to or greater than the lower level, then fog (F) is selected. A final temperature test is considered to detect the rare event of ice fog (IF).

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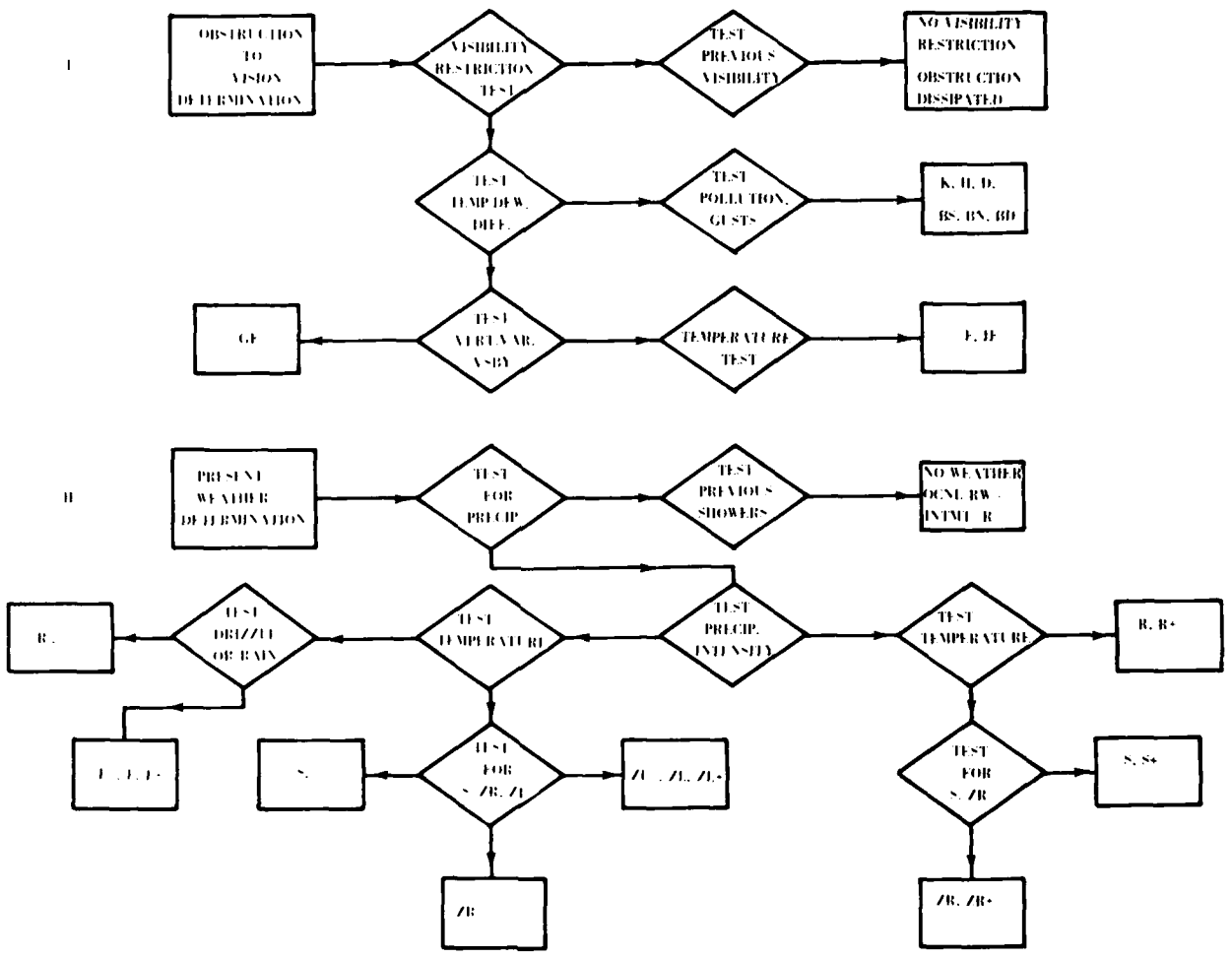


Figure 2. Flow Charts of Obstruction to Vision and Present Weather Determination Program

3.2 Present Weather Program

The lower diagram of Figure 2 depicts the flow diagram for the present weather (PW) section of the decision-tree program. It is activated by one tip of the heated tipping-bucket rain gage. Validity checks with the FSM's then determine whether the tip is spurious, an infrequent occurrence.

The determination of precipitation intensity divides the program into two major branches—light precipitation to the left, moderate and heavy to the right. Temperature tests are performed next and if the temperature is less than 0.5°C the flow is directed to the "frozen" branch. At that point tests are made to determine if the VIDE is significantly greater (50%) than the FSM. If it is, then snow (S) is reported. If it is not, then another test is made between the FSM and the TRANS. If they are similar, freezing drizzle (ZL) is reported. The drizzle category is classified further into light, moderate, or heavy, depending on visibility criteria.

If the temperature is equal to or greater than 0.5°C, the flow proceeds to the "liquid" branches which consist of rain and drizzle. The primary test in the light precipitation branch is the comparison of FSM and TRANS to discriminate between rain (R) and drizzle (L). Drizzle (L) is then further classified as light, moderate, or heavy, depending on the visibility. An additional test, a comparison of VIDE and FSM, is performed in this branch if the temperature is less than 3°C. If the VIDE exceeds the FSM significantly (50%), the decision tree will select snow.

4. OBSERVATIONS

The total decision-tree program (AUTO) produced 1-min averages of all observed meteorological variables together with the determination of the present weather (PW) and obstruction to vision (OV). Several samples have been selected to illustrate the versatility of the program and to show the comparable human observations.

The first sample, Figure 3, shows data collected on 8 June 1978 between 0900 and 0959 GMT. It was selected to illustrate the capability of the program to depict the rapidly changing weather conditions during a thunderstorm. Column 1 indicates the time of observation by minute. Columns 2 through 6 are values of extinction coefficient ($\times 10^{-4}$ m^{-1}) measured by FSM's at four levels of Tower A(A200-57 m, A150-48 m, A100-29 m, and A50-16 m) and at the 3 m level at site X. Column 7 contains the extinction coefficients measured by the TRANS. Columns 8 through 17 depict the 1-min averages of temperature (TMP X10degrees C) at the FSM levels of Tower A, followed by the temperature-dew point difference (DPS) at the same heights. Column 18 shows a 1-min count of the number of tips made by the rain gage (each tip denotes 0.005 in. of precipitation). The next

column, 19, gives the extinction coefficient ($X10^{-4}$, $^{-1}$) obtained from the nephelometer (NEPH). Column 20 displays the back scatter meter (VIDE) observation of extinction coefficient; column 21, the decision-tree program's determination of the present weather and obstruction to vision; and finally, the last column, the weather observations recorded by the FAA observer for the same period.

The major features of interest are the periods of intense rain reflected in the higher extinction coefficient (lower visibilities) of the visibility instrument, columns 2 through 7 and 20; the rain-count produced by the tipping-bucket rain gage, column 18; the observations by the present weather program (on a minute-by-minute basis); and the corresponding observations by the FAA observer. It is apparent that the AUTO is more capable than a human in tracking rapidly changing weather events.

The next example, Figure 4, was selected to illustrate the AUTO observations generated during a period of haze. The principal instruments used by the AUTO to determine haze are the vertical array of visibility meters, FSM (columns 2 through 6); the temperature-dew point sets, TMP and DPS (columns 8 through 17); and the nephelometer, NEPH (column 19).

The vertical profile of visibility (columns 2 through 6) shows a restriction to visibility at the lowest level which increases with height. The 60-min of observation also show the increase in this visibility restriction with time. The initial minute contained EXCO's sufficiently high to activate a search for visibility obstruction. The temperature-dew point values (columns 8 through 17) indicate high humidities, but prior to selecting fog as an observation the AUTO examines the nephelometer (NEPH) reading (column 19). Comparison of the magnitude of the NEPH with the X FSM shows their equivalence, therefore, AUTO selects haze (H) for the observations. The one FAA observation at 0255 GMT shows a similar determination.

The next illustration, Figure 5, was selected to demonstrate the AUTO observations during the hour that followed Figure 4. At the beginning of the hour the comparison of the NEPH and the X FSM resulted in a haze (H) selection alone. However, the FSM's at Site X began to observe lower visibilities as the hour proceeded and quickly exceeded the NEPH in magnitude. Since there was also a significant restriction measured by the NEPH, AUTO chose fog and haze (FH) for the observation during most of the hour; the FAA observation at 0355 GMT indicates the same phenomena.

The vital role of the tower FSM's in determining ground fog (GF) is illustrated in Figure 6. The period of observation occurred between 0600 and 0659 GMT on 4 November 1978. The lowest level FSM located at X (column 6) recorded an extremely high EXCO throughout the hour and is in good agreement with the other ground-based visibility instruments at the X-location, TRANS (column 7) and VIDE

(column 20). At the same time, the EXCO's measured at the higher levels of the tower (columns 2 through 5) show increasing visibility with height throughout the hour, indicating that the obstruction to vision was a shallow phenomenon. The AUTO determined ground fog (GF) as the most appropriate obstruction. The FAA observer at 0655 GMT reported ground fog in all quadrants.

The next illustration, Figure 7, was selected to show the response of the AUTO during a period of snow. The data were collected on 7 February 1979 between 2300 and 2359 GMT. The extinction coefficient measured by the tower FSM's (columns 2 through 6) show very little variation in the vertical, a characteristic of snow or rain. The temperature and dew point readings (columns 8 through 17) record temperatures (-5 to -6°C) below freezing and dew point spreads of 1 to 2°. The nephelometer (NEPH) shows no significant contribution to the extinction coefficient from atmospheric particles. The significant instrument during this period is the VIDE. Comparison of the VIDE with the FSM at X shows it to be well over 50% greater; therefore, the AUTO selected snow (S) as the phenomenon that was occurring. The FAA observer, at 2323 and 2357 GMT also reported snow.

The final figure in this section, Figure 8, illustrates the capacity of the AUTO to respond to varying types of weather. The first 8 min of the hour contain observations of freezing rain and fog changing to rain and fog. Criteria used to determine weather for these observations were visibility restrictions; occurrence of a rain tip in the previous 5 min; similarity of EXCO's measured by VIDE and the FSM at X; and an initial temperature just above 0°C, followed by an upward trend of temperatures.

From 0108 to 0138 GMT the VIDE exceeded the FSM at X by more than 50%. Therefore, AUTO selected snow. During the same period the vertical profile of EXCO's showed a sharp decrease in visibility with height, not a normal profile for snow alone. Therefore, the AUTO also continued the fog observation.

At 0139 GMT, the EXCO values of the VIDE dropped so that they no longer exceeded the FSM values at X by 50%. The rain gage still indicated that precipitation was occurring and that temperature was increasing. Therefore, AUTO selected light rain and fog as the appropriate determination.

The verification of this type episode is difficult unless an observer is located at the same site and is devoting his full time to monitoring the weather. The FAA observation at 0155 GMT specifies light rain mixed with snow. The AUTO, because it was not programmed to report snow and rain at the same time, did a good job of selecting the predominant feature at each minute. The end result is a creditable specification of the weather events occurring during this particular hour.

METRIC UNITS
HOUR BEGINNING: 8JN08/0900

	A200 FSM	A150 FSM	A100 FSM	A50 FSM	X FSM	MN TRN	A200 TMP	A200 DPS	A150 TMP	A150 DPS	A100 TMP	A100 DPS	A50 TMP	A50 DPS	X TMP	X DPS	RAIN	NEFH	VIDE	WEATHER	FAA
0	9.3	12.8	12.1	11.0	9.4	8	171	-6	175	6	169	-5	176	9	175	6	101	1	15	R,F	
1	7.3	10.1	9.3	8.9	9.6	7	172	-6	176	6	169	-5	177	9	176	5	102	1	13	R,F	
2	10.0	14.2	12.3	11.3	11.7	8	171	-6	175	6	169	-6	176	9	176	5	103	1	10	R,F	
3	9.4	14.9	12.0	11.5	9.6	7	172	-6	176	6	169	-6	176	9	176	4	104	1	13	R,F	
4	7.4	10.5	8.8	8.4	7.9	6	171	-7	175	6	169	-6	176	9	176	4	104	1	13	R,F	
5	7.1	9.7	8.3	7.6	8.1	6	171	-7	175	6	169	-6	176	9	176	1	105	1	13	R,F	
6	7.6	9.9	8.8	8.6	9.2	7	171	-7	175	6	169	-6	176	8	176	2	105	1	14	R,F	
7	10.1	14.4	11.0	10.3	11.5	8	171	-7	175	6	168	-6	176	9	176	2	106	1	16	R,F	
8	17.9	24.6	18.8	18.3	26.3	12	171	-7	175	5	168	-6	176	8	175	2	109	1	25	R,F	
9	27.5	39.9	30.7	32.3	49.1	20	171	-7	175	6	168	-6	176	8	175	2	115	1	41	R,F	
10	42.7	61.1	48.1	46.6	78.3	28	171	-7	175	5	168	-6	175	8	176	3	119	1	45	R,F	
11	42.7	55.7	47.9	51.8	30.8	17	171	-7	175	6	168	-7	175	8	175	4	121	1	42	R,F	
12	30.3	47.1	33.8	38.5	47.0	17	172	-7	176	6	169	-6	177	9	176	4	127	1	37	R,F	
13	42.1	58.4	46.3	51.6	60.3	23	171	-7	175	5	168	-7	176	8	176	4	131	1	45	R,F	
14	52.1	66.2	61.9	64.6	67.6	31	171	-8	175	5	168	-7	176	8	176	4	135	1	59	R,F	
15	62.9	78.3	73.3	77.9	93.2	39	171	-7	175	5	168	-7	175	7	176	4	140	1	60	R,F	
16	73.4	90.2	90.3	96.2	99.3	47	171	-8	175	5	168	-8	175	7	176	4	145	1	72	R,F	
17	63.4	77.9	81.4	83.6	95.8	43	172	-7	176	5	168	-7	176	7	176	3	151	1	62	R,F	RF
18	48.2	66.7	65.5	70.3	51.3	28	172	-7	176	5	168	-7	176	7	176	7	156	1	47	R,F	
19	45.6	67.3	59.7	63.8	67.1	34	172	-8	176	5	168	-8	176	7	176	10	159	1	56	R,F	
20	43.2	59.4	57.3	59.0	63.0	30	172	-8	176	5	168	-8	176	7	176	8	165	1	48	R,F	
21	64.6	82.8	80.8	81.4	93.1	44	171	-8	176	5	168	-8	176	7	176	7	169	1	67	R,F	
22	57.0	73.1	70.2	80.1	80.8	43	172	-8	176	5	168	-8	176	7	176	7	172	1	58	R,F	
23	45.2	65.7	66.5	68.8	66.0	37	173	-7	177	5	169	-8	176	7	177	6	174	1	51	R,F	TRF
24	32.3	50.3	53.3	54.3	51.8	30	173	-7	177	5	170	-8	177	8	177	5	185	1	50	R,F	
25	15.9	27.6	24.9	27.1	14.5	11	174	-7	178	5	170	-7	179	9	178	5	187	1	18	R,F	
26	9.6	15.6	14.0	14.9	11.8	9	174	-6	178	5	171	-7	179	9	178	5	188	1	14	R,F	
27	6.7	10.5	9.8	10.0	7.5	7	174	-7	178	5	171	-7	180	9	178	4	188	1	10	R,F	
28	5.9	8.5	8.2	7.9	7.5	7	174	-7	178	5	171	-7	180	9	177	4	188	1	12	R,F	
29	6.5	9.6	9.3	9.0	9.4	8	175	-6	178	5	171	-7	179	9	178	3	188	1	12	R,F	
30	7.9	10.8	10.4	10.0	13.9	8	174	-7	178	5	170	-7	179	9	178	3	189	1	15	R,F	
31	9.6	14.4	13.2	12.7	12.9	9	174	-7	176	5	170	-7	179	8	178	2	189	1	15	R,F	
32	8.5	12.1	11.5	11.2	11.4	8	174	-7	177	5	170	-8	179	8	178	3	189	1	14	R,F	
33	9.1	13.0	12.1	11.7	12.3	9	174	-7	178	5	171	-7	179	8	178	2	190	1	13	R,F	
34	8.8	11.6	11.2	11.0	8.3	7	174	-7	178	5	170	-7	179	8	178	3	190	1	11	R,F	
35	8.3	10.8	10.7	10.4	8.1	7	174	-7	178	5	170	-7	179	8	178	2	190	1	12	R,F	
36	6.8	8.9	8.9	8.6	6.8	6	175	-7	178	5	171	-7	179	8	178	3	190	1	8	R,F	
37	5.9	7.6	7.5	7.2	7.6	6	175	-7	178	5	171	-7	180	9	178	3	190	1	9	R,F	
38	5.1	6.4	6.4	6.5	4.2	5	175	-7	178	5	171	-7	180	8	179	3	190	1	7	R,F	
39	5.6	6.8	6.7	6.5	7.3	6	174	-7	178	5	171	-7	180	9	178	2	190	1	9	R,F	
40	6.3	7.2	7.3	7.4	5.2	5	174	-7	178	5	171	-7	179	8	178	2	190	1	8	R,F	
41	8.2	7.5	7.1	7.4	10.2	7	175	-7	178	5	171	-7	179	8	178	2	190	1	11	R,F	TR-F
42	7.4	9.2	8.9	9.2	9.4	7	175	-7	178	5	171	-7	180	8	178	1	191	1	10	R,F	
43	6.5	8.3	8.1	8.1	9.2	6	175	-7	178	5	171	-7	180	9	178	1	191	1	11	R,F	
44	8.8	10.3	9.7	9.5	12.9	8	174	-7	177	5	171	-7	179	8	178	2	191	1	13	R,F	
45	12.7	19.5	16.2	16.9	25.6	13	175	-7	178	5	171	-7	180	9	179	2	193	1	22	R,F	
46	13.4	18.3	16.8	17.1	22.1	11	175	-7	178	5	172	-7	180	9	179	2	194	1	19	R,F	
47	13.3	19.1	16.8	17.3	23.1	11	176	-6	179	6	172	-7	180	9	179	2	195	1	18	R,F	
48	13.1	18.1	16.2	16.9	13.4	9	176	-7	179	5	172	-7	181	9	179	2	196	1	15	R,F	
49	12.5	15.8	15.2	15.2	14.8	9	176	-7	179	5	172	-7	180	8	179	1	197	1	17	R,F	
50	12.2	14.9	14.7	14.9	13.5	9	175	-7	179	5	172	-7	180	8	180	2	198	1	15	R,F	
51	8.9	10.7	10.7	10.7	10.8	7	175	-7	179	5	172	-7	180	8	180	1	198	1	10	R,F	
52	7.8	9.9	9.7	9.6	10.6	7	175	-7	179	5	172	-7	181	9	180	1	198	1	11	R,F	
53	7.3	9.2	9.3	9.6	8.2	6	175	-7	178	5	172	-7	181	9	179	1	198	1	14	R,F	
54	7.9	9.5	9.3	9.8	11.5	8	174	-8	177	5	171	-7	180	8	178	1	198	1	13	R,F	
55	9.3	11.5	11.4	11.3	12.7	8	173	-8	176	5	170	-7	179	8	177	-1	199	1	13	R,F	
56	9.1	12.5	11.9	11.9	14.8	9	173	-8	176	5	170	-7	178	8	177	-1	199	1	13	R,F	
57	10.9	15.4	13.6	13.7	22.6	12	171	-9	174	4	168	-7	177	8	175	-2	200	1	16	R,F	
58	11.4	17.5	14.9	15.7	13.6	10	171	-8	174	5	168	-6	176	8	174	-1	201	1	15	R,F	
59	8.9	13.5	11.7	12.3	10.0	7	171	-6	174	5	168	-6	175	8	173	-1	202	1	11	R,F	

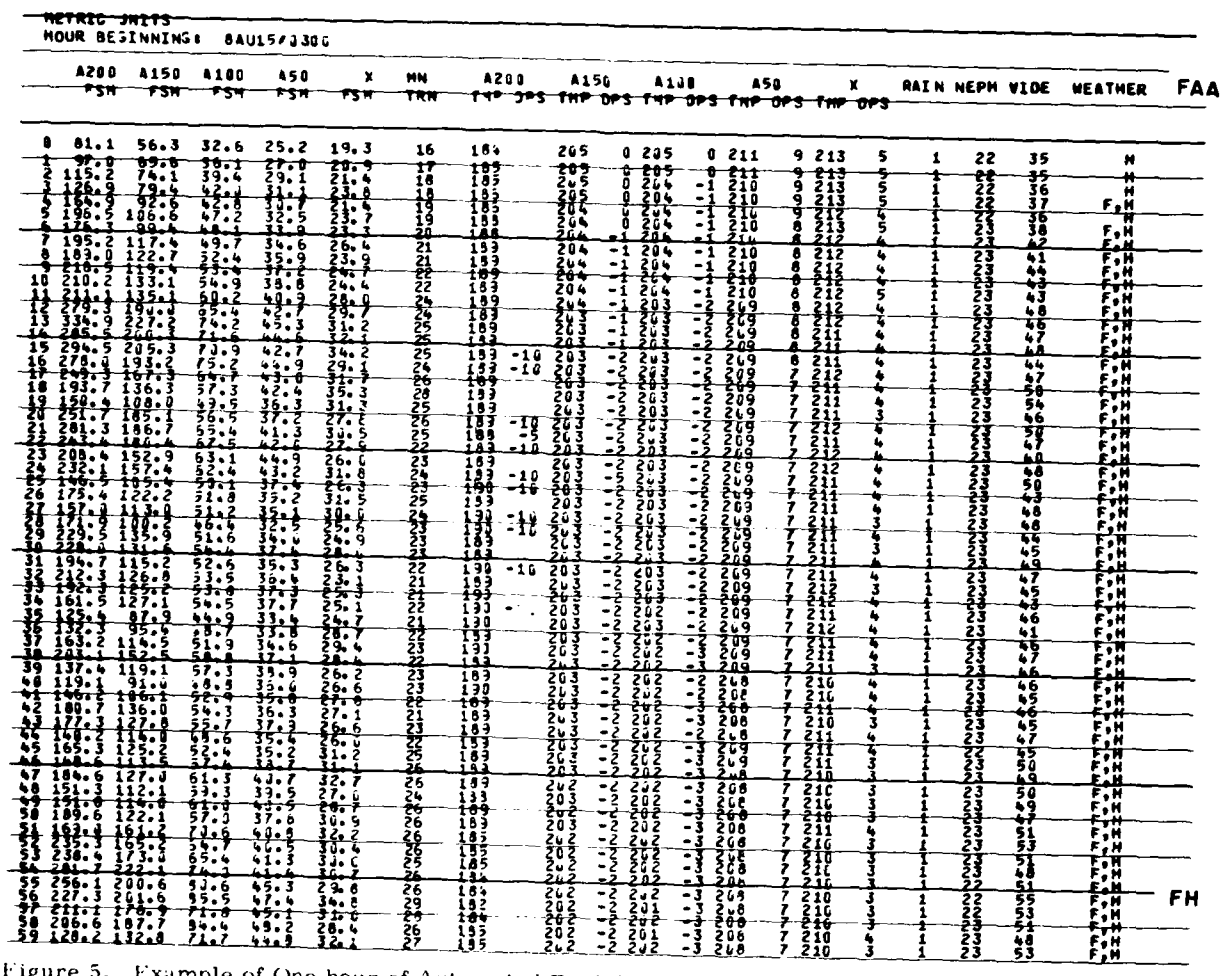
Figure 3. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0900 GMT, 8 June 1978. FAA weather observations are plotted at extreme right

METRIC UNITS

HOUR BEGINNING: 8AU15/0200

	A200	A150	A100	A50	X	MN	A200		A150		A100		A50		X		RAIN	NEPH	VIDE	WEATHER	FAA
	PSN	PSN	PSN	PSN	PSN	TRN	FRQ	OPS	TMP	OPS	TMP	OPS	TMP	OPS	TMP	OPS					
0	12.5	12.2	11.3	10.6	9.4	6	198	-6	213	8	212	7	217	16	218	10	1	17	18	H	
1	12.7	12.4	11.5	10.7	9.6	6	197	-7	213	8	212	7	217	15	218	10	1	17	16	H	
2	13.1	12.7	11.3	10.9	9.5	6	196	-7	213	8	213	7	217	15	218	10	1	17	19	H	
3	13.6	13.1	11.8	10.9	9.9	6	195	-6	213	7	212	7	217	15	218	10	1	17	19	H	
4	13.6	13.3	11.9	11.6	9.4	6	195	-8	212	7	212	7	217	15	218	10	1	17	17	H	
5	13.9	13.5	12.3	11.3	9.8	7	196	-8	212	7	212	6	217	15	217	10	1	17	19	H	
6	14.5	14.0	12.3	11.3	10.7	7	193	-9	212	7	212	6	217	15	217	9	1	17	20	H	
7	15.1	14.4	12.5	11.4	10.6	7	195	-9	212	6	212	6	217	15	217	9	1	17	18	H	
8	15.4	14.7	13.0	12.1	10.5	7	194	-9	212	7	211	6	216	14	217	9	1	17	18	H	
9	15.7	15.3	13.1	12.0	10.7	7	194	-10	212	6	211	5	216	14	217	9	1	17	20	H	
10	15.5	14.9	13.3	12.4	11.0	7	193		212	6	211	5	216	14	217	9	1	17	19	H	
11	16.5	15.6	13.6	12.4	10.8	7	197	-7	211	6	211	5	216	14	216	9	1	17	19	H	
12	16.3	16.0	14.1	12.7	10.6	8	195	-7	211	6	211	5	216	13	217	9	1	17	19	H	
13	17.4	16.6	14.5	13.0	12.0	8	195	-8	211	5	210	4	215	13	217	8	1	18	21	H	
14	17.7	16.7	14.5	13.2	11.7	8	195	-8	211	5	210	4	215	13	216	8	1	18	20	H	
15	17.8	16.7	14.6	13.2	11.1	8	195	-8	211	5	210	4	215	13	217	8	1	18	21	H	
16	18.4	17.2	15.0	13.6	12.2	8	195	-8	210	5	210	4	215	13	216	8	1	18	23	H	
17	18.2	17.2	15.0	13.6	11.2	8	195	-7	210	5	210	4	215	13	216	8	1	18	22	H	
18	20.1	18.8	15.5	13.9	11.3	8	198	-5	210	5	210	4	215	12	217	8	1	18	22	H	
19	21.9	20.4	16.1	14.2	12.5	9	198	-5	210	4	209	3	215	12	216	8	1	18	21	H	
20	20.8	20.0	16.5	14.5	12.8	9	198	-5	210	4	209	3	215	12	216	8	1	18	24	H	
21	21.6	20.1	16.6	14.6	12.6	9	198	-4	209	4	209	3	214	12	216	7	1	18	25	H	
22	19.4	18.9	15.7	14.7	12.9	9	197	-5	210	4	209	3	214	12	215	7	1	18	22	H	
23	20.3	19.2	16.3	14.6	12.8	9	197	-6	210	4	209	3	214	12	216	7	1	18	23	H	
24	23.3	21.4	17.2	15.1	14.6	10	196	-6	209	4	209	3	214	12	216	7	1	19	22	H	
25	23.8	22.1	18.0	15.7	14.7	10	193	-6	209	3	208	3	214	12	216	7	1	19	24	H	
26	24.8	22.8	18.3	16.2	14.7	10	195	-6	209	3	208	2	214	11	216	7	1	19	27	H	
27	24.1	22.6	18.8	16.9	14.6	11	194	-7	209	3	208	2	213	11	215	6	1	19	25	H	
28	26.4	24.1	19.4	17.0	14.7	11	193	-8	209	3	208	2	213	11	215	7	1	19	25	H	
29	25.3	23.2	18.9	16.9	15.2	11	195	-5	209	3	208	2	213	11	215	6	1	19	27	H	
30	24.9	24.1	19.5	17.0	16.3	11	196	-6	208	3	208	2	213	11	214	6	1	19	27	H	
31	22.5	22.6	19.5	17.6	13.4	11	192	-8	208	3	208	2	213	11	215	6	1	19	25	H	
32	23.9	22.2	19.1	17.4	15.2	11	188		208	3	208	2	213	11	215	6	1	19	25	H	
33	26.0	24.3	19.9	17.9	14.6	11	189		208	2	207	2	213	10	215	6	1	19	26	H	
34	26.2	24.2	20.0	17.9	15.3	11	195	-10	208	2	207	2	213	11	214	6	1	20	28	H	
35	25.0	24.0	19.7	17.5	15.1	11	191	-7	208	2	207	1	213	10	214	6	1	20	27	H	
36	26.0	24.1	19.3	17.4	16.5	12	189	-7	208	2	207	1	213	10	214	6	1	20	28	H	
37	25.0	23.3	19.9	17.6	15.6	12	193	-6	208	2	207	1	213	10	214	6	1	20	29	H	
38	26.4	24.0	19.4	17.6	13.9	11	193	-6	208	2	207	1	213	11	215	6	1	20	27	H	
39	28.4	27.2	21.4	18.2	15.9	12	193	-5	207	2	207	1	213	10	215	6	1	20	31	H	
40	23.1	26.5	20.9	18.1	15.1	12	189	-7	207	1	207	1	213	10	214	6	1	20	26	H	
41	29.5	27.4	22.0	18.9	16.1	12	193		207	2	207	1	213	10	214	6	1	20	27	H	
42	26.0	24.6	21.6	19.0	14.9	12	189		207	1	207	1	212	10	214	6	1	20	27	H	
43	31.9	28.6	22.2	18.9	14.6	12	194		207	2	207	1	212	10	214	5	1	20	26	H	
44	28.0	27.4	20.9	18.3	15.8	11	195		207	2	207	1	212	10	214	6	1	20	27	H	
45	30.6	26.6	21.7	18.9	15.2	12	193	-6	207	2	206	1	212	10	214	6	1	20	26	H	
46	24.8	24.3	21.0	19.0	14.7	12	191	-6	207	1	206	1	212	10	215	6	1	21	25	H	
47	24.2	23.3	20.4	18.7	16.4	12	193	-10	207	2	206	1	212	10	214	6	1	21	31	H	
48	31.6	27.0	20.8	18.2	15.4	12	189		207	2	206	1	212	10	214	6	1	21	27	H	
49	30.8	27.3	21.4	19.2	15.9	13	193		207	2	206	1	212	10	214	6	1	21	29	H	
50	32.2	28.5	22.1	19.8	15.1	12	193	-10	206	2	206	1	212	10	214	6	1	21	28	H	
51	36.1	31.2	22.9	18.8	17.2	13	193		206	1	206	1	212	10	214	6	1	21	28	H	
52	37.0	32.8	24.0	19.7	16.7	13	193	-3	206	1	206	1	212	10	214	5	1	21	31	H	
53	40.1	34.2	25.4	21.7	17.2	13	193		206	1	205	0	211	10	213	5	1	21	31	H	H
54	43.5	37.3	25.8	22.9	16.7	14	193		206	1	206	1	212	10	214	6	1	21	32	H	
55	40.9	36.4	26.3	21.5	18.9	14	193		206	1	205	0	211	10	213	6	1	21	33	H	
56	41.2	37.2	26.6	22.0	18.8	14	193		206	1	205	1	211	9	213	5	1	21	33	H	
57	42.6	39.2	27.1	23.6	18.3	14	193		205	1	205	0	211	9	213	5	1	21	33	H	
58	52.6	42.4	28.4	23.4	20.5	15	189		205	1	205	0	211	9	213	5	1	21	33	H	
59	63.6	46.4	29.6	23.7	24.8	16	194		205	1	205	1	211	9	212	5	1	22	35	H	

Figure 4. Example of One hour of Automated Decision-Tree Program Output Beginning at 0200 GMT, 15 August 1978. FAA weather observations are plotted at extreme right



METRIC UNITS
HOUR BEGINNING: 8AU15/0300

	A200 FSW	A150 FSW	A100 FSW	A50 FSW	X FSW	MN TRN	A200 THP	A200 DPS	A150 THP	A150 DPS	A100 THP	A100 DPS	A50 THP	A50 DPS	X THP	X DPS	RAIN	NEPH	VIDE	WEATHER	FAA
0	81.1	56.3	32.6	25.2	19.3	16	184		205	0	205	0	211	9	213	5	1	22	35	M	
1	99.0	69.8	38.1	27.0	20.9	17	185		205	0	205	0	211	9	213	5	1	22	35	M	
2	115.2	74.1	39.4	29.1	21.4	18	185		205	0	204	-1	210	9	213	5	1	22	36	M	
3	126.9	79.5	42.4	31.1	23.8	18	183		205	0	204	-1	210	9	213	5	1	22	37	F,M	
4	154.3	92.6	45.8	34.7	24.4	19	185		204	0	204	-1	210	9	212	4	1	23	36	F,M	
5	196.5	106.6	47.2	32.5	23.7	19	185		204	0	204	-1	210	8	213	5	1	23	38	F,M	
6	176.3	99.4	48.1	33.8	23.3	20	188		204	-1	204	-1	210	8	212	4	1	23	42	F,M	
7	195.2	117.4	49.7	34.6	26.4	21	193		204	-1	204	-1	210	8	212	4	1	23	41	F,M	
8	183.0	122.7	52.4	35.9	23.9	21	193		204	-1	204	-1	210	8	212	4	1	23	41	F,M	
9	210.5	119.4	53.9	37.2	24.7	22	189		204	-1	204	-1	210	8	212	4	1	23	44	F,M	
10	210.2	133.1	54.9	38.8	24.4	22	193		204	-1	204	-1	210	8	212	5	1	23	43	F,M	
11	211.1	135.1	60.2	40.9	28.0	24	189		204	-1	203	-2	209	8	212	4	1	23	43	F,M	
12	279.3	194.4	95.4	43.7	29.7	26	189		203	-1	203	-2	209	8	212	4	1	23	48	F,M	
13	334.9	227.2	74.2	45.3	31.2	26	189		203	-1	203	-2	209	8	212	4	1	23	46	F,M	
14	285.5	200.3	71.6	44.0	32.1	25	192		203	-1	203	-2	209	8	211	4	1	23	47	F,M	
15	294.5	205.3	73.9	42.7	34.2	25	193	-10	203	-1	203	-2	209	8	211	4	1	23	48	F,M	
16	278.4	193.2	75.2	44.9	29.1	24	193	-10	203	-2	203	-2	209	8	211	4	1	23	44	F,M	
17	249.3	167.3	64.7	43.0	31.7	26	189		203	-2	203	-2	209	7	212	4	1	23	47	F,M	
18	193.7	136.3	57.3	42.4	35.3	28	193		203	-2	203	-2	209	7	211	4	1	23	50	F,M	
19	150.4	108.0	49.5	36.3	31.2	25	183		203	-2	203	-2	209	7	211	4	1	23	54	F,M	
20	251.7	185.1	56.5	37.2	27.5	26	183	-10	203	-2	203	-2	209	7	211	3	1	23	46	F,M	
21	281.3	186.7	55.4	41.3	30.5	25	188	-5	203	-2	203	-2	209	7	212	4	1	23	50	F,M	
22	243.4	180.4	67.5	42.5	27.5	22	183	-10	203	-2	203	-2	209	7	211	4	1	23	47	F,M	
23	208.4	152.9	63.1	44.9	26.0	23	189		203	-2	203	-2	209	7	212	4	1	23	48	F,M	
24	232.1	157.4	52.4	43.2	31.8	24	193	-10	203	-2	203	-2	209	7	212	4	1	23	48	F,M	
25	246.2	169.4	59.1	37.4	26.3	23	190	-10	203	-2	203	-2	209	7	211	4	1	23	50	F,M	
26	175.4	122.2	51.8	39.2	31.5	25	193		203	-2	203	-2	209	7	211	4	1	23	43	F,M	
27	157.4	111.0	51.2	38.1	30.9	24	190	-10	203	-2	203	-2	209	7	211	4	1	23	48	F,M	
28	171.8	114.8	51.2	32.1	30.9	24	190	-10	203	-2	203	-2	209	7	211	3	1	23	48	F,M	
29	229.5	148.9	46.4	32.5	25.6	23	190	-10	203	-2	203	-2	209	7	211	4	1	23	46	F,M	
30	228.3	135.9	51.6	34.4	24.9	23	189		203	-2	203	-2	209	7	211	3	1	23	45	F,M	
31	194.7	115.2	52.6	35.3	26.3	22	190	-10	203	-2	203	-2	209	7	211	4	1	23	47	F,M	
32	212.3	126.8	53.5	36.4	23.1	21	193		203	-2	203	-2	209	7	212	3	1	23	45	F,M	
33	192.3	125.2	53.8	37.3	25.1	24	193		203	-2	203	-2	209	7	212	4	1	23	43	F,M	
34	161.5	127.1	54.5	37.7	25.1	22	190		203	-2	202	-2	209	7	211	4	1	23	46	F,M	
35	125.4	87.9	44.9	33.4	24.7	21	190		203	-2	203	-2	209	7	212	4	1	23	41	F,M	
36	132.3	95.6	48.7	33.8	28.7	22	193		203	-2	202	-2	209	7	211	4	1	23	46	F,M	
37	163.2	114.5	51.9	34.6	29.4	23	191		203	-2	202	-3	209	7	211	4	1	23	47	F,M	
38	203.1	152.5	58.8	37.1	28.4	22	193		203	-2	202	-3	209	7	211	3	1	23	46	F,M	
39	137.4	119.1	57.3	35.9	26.2	23	189		203	-2	202	-2	208	7	210	4	1	23	46	F,M	
40	119.1	91.0	48.5	35.6	26.6	23	190		203	-2	202	-2	208	7	210	4	1	23	45	F,M	
41	140.2	106.1	52.0	35.0	27.0	22	189		203	-2	202	-3	208	7	211	4	1	23	46	F,M	
42	180.7	136.0	54.3	36.3	27.1	21	189		203	-2	202	-3	208	7	210	3	1	23	45	F,M	
43	177.3	127.8	55.7	37.3	26.6	23	189		203	-2	202	-2	208	7	211	4	1	23	47	F,M	
44	148.2	116.8	48.6	35.4	26.0	22	193		203	-2	202	-3	209	7	211	4	1	22	45	F,M	
45	169.3	125.2	52.4	35.2	31.2	25	189		203	-2	202	-3	209	7	211	3	1	23	50	F,M	
46	148.6	113.5	57.4	38.7	31.1	26	193		203	-2	202	-3	208	7	210	3	1	23	49	F,M	
47	184.6	127.0	61.3	40.7	32.7	26	189		202	-2	202	-3	208	7	210	3	1	23	50	F,M	
48	151.3	112.1	59.3	39.5	27.6	24	193		203	-2	202	-3	208	7	210	3	1	23	49	F,M	
49	191.0	126.0	61.0	40.5	28.7	26	189		202	-2	202	-3	208	7	210	3	1	23	47	F,M	
50	189.6	122.1	57.0	37.6	30.9	26	189		203	-2	202	-3	208	7	211	4	1	23	51	F,M	
51	163.4	161.2	71.6	40.8	32.2	26	185		202	-2	202	-3	208	7	210	3	1	23	53	F,M	
52	210.3	164.6	74.7	46.5	30.4	26	185		202	-2	202	-3	208	7	210	3	1	23	53	F,M	
53	238.4	173.5	65.4	41.3	34.0	25	185		202	-2	202	-3	208	7	211	3	1	23	51	F,M	
54	281.7	222.1	76.3	41.4	30.7	26	188		202	-2	202	-3	208	7	210	3	1	23	48	F,M	
55	256.1	200.6	93.6	45.3	29.8	26	183		202	-2	202	-3	208	7	210	3	1	22	51	F,M	FH
56	227.3	201.6	85.5	47.4	34.8	29	192		202	-2	201	-3	208	7	210	3	1	22	55	F,M	
57	211.1	178.9	71.8	45.1	32.0	26	184		202	-2	202	-3	208	7	210	3	1	22	53	F,M	
58	206.6	187.7	94.4	48.2	28.4	26	193		202	-2	201	-3	208	7	210	3	1	23	51	F,M	
59	128.2	132.8	71.7	44.8	32.1	27	185		202	-2	202	-3	208	7	210	3	1	23	53	F,M	

Figure 5. Example of One hour of Automated Decision-Tree Program Output Beginning at 0300 GMT, 15 August 1978. FAA weather observations are plotted at extreme right

METRIC UNITS
HOUR BEGINNING: ANO16/J60G

	A200 FSM	A150 FSM	A100 FSM	A50 FSM	X FSM	MN TRN	A20J TMP	DPS	A15J TMP	DPS	A10C TMP	DPS	A5J TMP	DPS	X TMP	DPS	RAIN	NEPH	WIDE	WEATHER	FAA
0	1.4	1.6	2.0	3.5	114.2	184	114	6	101	4	92	108	87	11	68	-2	0	2	151	GF	
1	1.4	1.7	2.6	3.8	115.2	175	103	4	98	3	92	107	84	8	47	-3	0	2	147	GF	
2	1.3	1.6	1.8	3.8	115.3	174	104	5	101	4	94	102	85	9	46	-3	0	2	146	GF	
3	1.4	1.7	1.9	4.3	107.3	158	103	4	100	4	93	106	85	11	52	-2	0	2	133	GF	
4	1.4	1.6	2.1	4.0	108.7	173	103	4	100	4	91	106	82	8	51	-2	0	2	124	GF	
5	1.4	1.6	1.9	2.9	114.1	154	102	4	100	4	93	101	82	9	52	-2	0	2	114	GF	
6	1.4	1.7	1.9	2.5	106.2	174	102	4	99	4	93	106	82	9	51	-2	0	2	146	GF	
7	1.3	1.6	2.0	2.6	98.4	158	103	5	100	4	93	103	81	6	50	-4	0	2	143	GF	
8	1.4	1.6	2.0	2.9	85.9	146	102	4	99	4	93	101	83	16	43	-8	0	2	125	GF	
9	1.5	1.7	1.9	3.4	72.6	113	102	4	99	4	93	104	83	11	49	-5	0	2	116	GF	
10	1.4	1.7	2.0	3.0	54.7	69	103	4	99	4	93	101	85	16	51	-2	0	2	92	GF	
11	1.4	1.6	1.9	2.9	62.2	85	103	4	99	4	93	106	86	11	47	-4	0	2	91	GF	
12	1.4	1.6	2.0	3.5	79.3	167	103	4	100	4	92	104	84	10	47	-4	0	2	131	GF	
13	1.4	1.6	2.0	3.6	116.2	231	103	5	99	4	93	102	83	11	46	-6	0	2	142	GF	
14	1.3	1.5	2.1	3.4	134.6	225	102	4	99	4	92	99	85	11	42	-6	0	2	187	GF	
15	1.3	1.5	2.1	4.1	129.4	222	102	5	99	4	93	102	83	9	47	-3	0	2	152	GF	
16	1.3	1.5	1.9	4.0	126.7	232	103	5	100	5	93	99	84	11	44	-4	0	2	149	GF	
17	1.3	1.5	2.2	4.0	125.6	227	102	5	99	4	92	99	84	14	50	-3	0	2	155	GF	
18	1.3	1.5	2.2	3.7	124.2	227	102	6	100	5	92	104	85	11	47	-3	0	2	143	GF	
19	1.3	1.6	2.2	4.1	126.9	225	102	4	99	3	92	102	84	14	47	-3	0	2	147	GF	
20	1.3	1.7	2.5	4.6	120.4	226	102	4	99	3	91	98	84	7	47	-3	0	2	157	GF	
21	1.3	1.6	2.7	3.9	125.2	238	102	4	100	3	91	101	84	11	47	-3	0	2	149	GF	
22	1.4	1.7	2.8	4.4	121.9	230	102	3	99	3	89	106	83	14	47	-2	0	2	156	GF	
23	1.3	1.6	2.4	5.6	125.3	232	102	4	99	3	91	99	79	5	47	-3	0	2	151	GF	
24	1.3	1.5	2.2	5.7	127.6	231	103	5	100	4	91	102	79	4	46	-4	0	2	154	GF	
25	1.3	1.5	2.0	3.5	138.6	244	102	4	99	4	92	102	86	11	53	-3	0	2	154	GF	
26	1.3	1.5	1.9	3.2	145.7	268	103	4	100	4	92	97	84	8	54	-4	0	2	152	GF	
27	1.3	1.5	2.0	2.5	148.5	274	103	5	99	4	92	101	85	13	55	-3	0	2	153	GF	
28	1.3	1.5	2.0	2.5	154.7	276	103	5	99	4	92	105	86	14	56	-3	0	2	156	GF	
29	1.3	1.4	2.1	2.6	165.7	291	103	5	101	5	91	98	86	16	56	-3	0	2	161	GF	
30	1.3	1.4	2.1	2.8	167.7	299	104	5	100	5	92	103	88	11	58	-3	0	2	157	GF	
31	1.3	1.4	2.1	3.1	168.6	313	104	5	101	6	92	101	86	8	57	-3	0	2	154	GF	
32	1.3	1.5	1.9	3.4	164.1	278	104	5	100	5	92	103	84	6	56	-2	0	2	147	GF	
33	1.2	1.4	1.8	3.7	145.7	240	104	6	101	6	92	107	84	8	57	-3	0	2	154	GF	
34	1.2	1.4	1.9	3.7	140.8	242	103	7	100	6	92	108	85	10	56	-3	0	2	154	GF	
35	1.2	1.4	1.9	3.0	142.5	250	103	7	100	6	93	106	87	11	56	-3	0	2	153	GF	
36	1.2	1.4	2.1	3.2	140.7	247	103	7	100	5	92	105	87	11	58	-3	0	2	155	GF	
37	1.2	1.4	2.1	3.6	140.4	264	104	7	101	6	91	105	85	11	55	-4	0	2	153	GF	
38	1.2	1.5	2.4	3.5	146.1	262	104	6	100	5	90	106	84	8	54	-3	0	2	153	GF	
39	1.3	1.4	2.4	3.4	147.6	259	104	5	101	5	89	106	83	8	54	-3	0	2	154	GF	
40	1.3	1.4	2.7	3.4	151.2	266	104	6	101	5	89	95	82	10	52	-4	0	2	150	GF	
41	1.2	1.4	2.8	3.2	156.4	263	103	6	99	5	88	102	82	11	54	-4	0	2	154	GF	
42	1.2	1.4	2.7	3.3	156.0	274	104	7	101	6	89	102	86	10	54	-3	0	2	154	GF	
43	1.2	1.3	2.7	2.9	152.7	278	104	8	101	7	90	106	87	13	54	-3	0	2	156	GF	
44	1.2	1.3	2.2	4.4	150.6	270	105	8	101	7	90	101	83	7	54	-2	0	2	157	GF	
45	1.1	1.3	2.6	3.9	142.9	259	105	8	102	8	91	99	85	9	55	-2	0	2	152	GF	
46	1.2	1.3	2.1	3.0	139.6	248	104	8	102	8	91	106	86	11	56	-2	0	2	149	GF	
47	1.2	1.3	2.5	2.8	139.4	242	104	8	102	7	93	103	86	12	54	-3	0	2	147	GF	
48	1.2	1.3	2.1	4.0	139.3	241	105	8	102	8	92	101	83	7	54	-3	0	2	144	GF	
49	1.1	1.3	1.9	3.7	139.1	237	104	8	102	8	92	96	87	11	56	-1	0	2	147	GF	
50	1.1	1.2	2.0	3.4	137.7	244	105	8	102	8	91	105	85	9	56	-2	0	2	146	GF	
51	1.1	1.3	2.1	4.9	149.5	257	104	8	101	8	90	104	85	6	56	-3	0	2	149	GF	
52	1.1	1.3	1.8	6.3	154.7	264	104	8	101	9	92	107	86	14	56	-2	0	2	150	GF	
53	1.2	1.2	1.9	5.7	158.1	281	104	8	101	8	91	104	86	11	56	-3	0	2	155	GF	
54	1.2	1.3	1.3	6.3	160.7	293	104	8	101	8	92	107	86	14	56	-3	0	2	158	GF	
55	1.2	1.3	1.7	6.4	164.6	294	104	8	101	8	93	102	87	11	56	-3	0	2	161	GF	
56	1.2	1.2	1.9	5.1	181.7	338	104	8	102	7	93	104	88	14	56	-3	0	2	162	GF	(GF)
57	1.1	1.2	1.7	4.0	187.7	322	104	8	102	8	93	106	87	11	56	-3	0	2	159	GF	
58	1.1	1.3	1.7	3.7	172.6	286	104	8	102	8	93	106	85	11	56	-4	0	2	154	GF	
59	1.2	1.2	1.5	4.8	157.1	254	104	7	102	8	93	104	84	9	56	-3	0	2	151	GF	

Figure 6. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0600 GMT, 4 November 1978. FAA weather observations are plotted at extreme right

Figure 7. Example of One Hour of Automated Decision-Tree Program Output Beginning at 2300 GMT, 7 February 1979. FAA weather observations are plotted at extreme right

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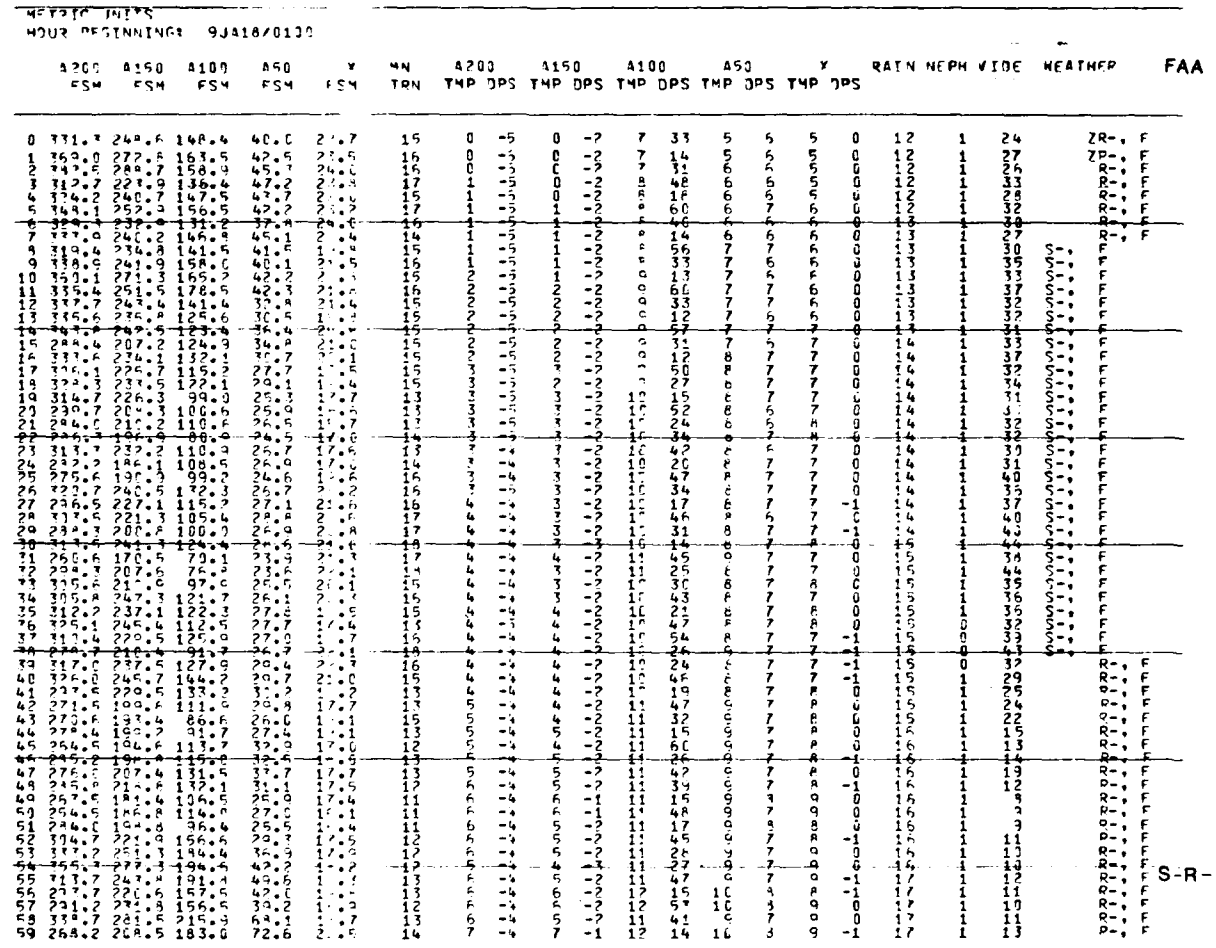

METRIC INPTS
HOUR BEGINNING: 79A18/0100

	A200 FSM	A150 FSM	A100 FSM	A50 FSM	Y FSM	MN TRN	A200 TMP	A200 DPS	A150 TMP	A150 DPS	A100 TMP	A100 DPS	A50 TMP	A50 DPS	Y TMP	Y DPS	RAIN	NEPH	VIDE	WEATHER	FAA
0	331.7	248.6	148.4	40.0	21.7	15	0	-5	0	-2	7	33	5	6	5	0	12	1	24	ZR-.	F
1	369.0	272.6	163.5	42.5	22.6	16	0	-5	0	-2	7	14	5	6	5	0	12	1	27	ZR-.	F
2	347.5	258.7	158.9	45.7	24.6	16	0	-5	0	-2	7	31	6	6	5	0	12	1	29	R-.	F
3	312.7	228.9	136.4	47.2	22.8	17	1	-5	0	-2	8	48	6	6	5	0	12	1	33	R-.	F
4	324.2	240.7	147.5	47.7	22.5	15	1	-5	0	-2	8	16	6	6	5	0	12	1	28	R-.	F
5	348.1	259.3	156.5	42.2	22.5	17	1	-5	1	-2	8	60	6	7	6	0	12	1	32	R-.	F
6	364.1	238.8	131.2	37.4	20.6	16	1	-5	1	-2	8	46	6	6	6	0	13	1	30	R-.	F
7	337.0	246.2	146.4	46.1	22.4	14	1	-5	1	-2	8	14	6	6	6	0	13	1	27	R-.	F
8	319.4	238.8	141.5	41.5	21.4	15	1	-5	1	-2	8	56	7	7	6	0	13	1	30	S-	F
9	338.6	241.9	158.0	40.1	22.5	16	1	-5	1	-2	8	33	7	6	6	0	13	1	35	S-	F
10	350.1	271.3	165.5	42.2	22.5	15	2	-5	1	-2	8	13	7	6	6	0	13	1	33	S-	F
11	335.4	251.5	178.5	42.3	21.6	16	2	-5	2	-2	8	60	7	7	6	0	13	1	37	S-	F
12	337.7	243.4	141.6	33.8	21.4	15	2	-5	2	-2	8	33	7	7	6	0	13	1	32	S-	F
13	335.6	238.8	125.6	30.5	19.5	15	2	-5	2	-2	8	12	7	6	6	0	13	1	32	S-	F
14	341.0	248.5	123.8	36.4	21.4	15	2	-5	2	-2	8	57	7	7	7	0	13	1	31	S-	F
15	288.6	207.2	124.9	34.8	20.6	15	2	-5	2	-2	8	31	7	7	7	0	14	1	33	S-	F
16	333.6	234.1	132.1	30.7	20.5	15	2	-5	2	-2	8	12	8	7	7	0	14	1	37	S-	F
17	316.1	226.7	115.2	27.7	19.5	15	3	-5	2	-2	8	50	8	7	7	0	14	1	32	S-	F
18	324.3	231.5	122.1	29.1	19.4	15	3	-5	2	-2	8	27	8	7	7	0	14	1	34	S-	F
19	314.7	226.3	99.0	25.3	17.7	13	3	-5	3	-2	10	15	8	7	7	0	14	1	31	S-	F
20	330.7	201.3	100.6	25.9	17.6	13	3	-5	3	-2	10	52	8	6	7	0	14	1	41	S-	F
21	284.6	211.2	110.6	26.5	18.7	17	3	-5	3	-2	10	24	8	6	8	0	14	1	32	S-	F
22	296.3	196.9	80.9	24.5	17.6	14	3	-5	3	-2	10	34	8	7	8	0	14	1	32	S-	F
23	313.7	232.2	110.9	26.7	17.6	13	3	-4	3	-2	10	42	8	7	7	0	14	1	30	S-	F
24	282.2	196.1	108.5	26.9	17.6	16	3	-4	3	-2	10	20	8	7	7	0	14	1	31	S-	F
25	275.2	195.9	99.2	24.6	17.6	16	3	-4	3	-2	10	47	8	7	7	0	14	1	40	S-	F
26	295.7	240.5	102.3	26.7	17.6	15	3	-4	3	-2	10	34	8	7	7	0	14	1	33	S-	F
27	296.6	227.1	115.0	27.1	21.6	16	4	-4	3	-2	10	17	8	7	7	-1	14	1	37	S-	F
28	317.6	221.3	105.4	28.8	21.6	17	4	-4	3	-2	10	46	8	6	7	0	14	1	40	S-	F
29	284.7	200.8	100.0	26.9	21.6	17	4	-4	3	-2	11	31	8	7	7	-1	14	1	42	S-	F
30	317.5	241.1	124.4	34.6	24.6	18	4	-4	3	-2	11	14	8	7	8	0	15	1	44	S-	F
31	260.6	170.5	79.1	23.9	21.6	17	4	-4	4	-2	11	45	8	7	7	0	15	1	36	S-	F
32	298.7	207.6	76.3	23.6	21.6	14	4	-4	3	-2	11	25	8	7	8	0	15	1	44	S-	F
33	315.8	217.0	97.0	26.5	20.6	15	4	-4	3	-2	11	30	8	7	8	0	15	1	35	S-	F
34	305.8	247.3	121.7	26.1	20.6	15	4	-4	3	-2	11	43	8	7	8	0	15	1	36	S-	F
35	312.2	237.1	122.3	27.5	21.5	15	4	-4	4	-2	11	21	8	7	8	0	15	1	36	S-	F
36	325.1	245.4	112.5	27.7	21.4	15	4	-4	4	-2	11	47	8	7	8	0	15	1	32	S-	F
37	311.4	229.5	125.9	27.9	21.7	16	4	-4	4	-2	11	54	8	7	7	-1	15	0	33	S-	F
38	279.7	218.4	91.7	26.7	21.6	18	4	-4	4	-2	11	26	8	7	7	-1	15	0	41	S-	F
39	317.0	237.5	127.9	29.4	21.7	16	4	-4	4	-2	10	24	8	7	7	-1	15	0	32	R-.	F
40	326.0	245.7	144.2	30.7	21.6	15	4	-4	4	-2	10	46	8	7	7	-1	15	1	29	R-.	F
41	297.6	229.6	133.2	31.2	21.7	13	4	-4	4	-2	11	19	8	7	8	0	15	1	25	R-.	F
42	271.5	198.6	111.6	29.8	17.7	13	5	-4	4	-2	11	47	8	7	8	0	15	1	24	R-.	F
43	270.6	193.4	86.6	26.0	17.1	15	5	-4	4	-2	11	32	8	7	8	0	15	1	22	R-.	F
44	278.4	198.2	91.7	27.4	17.1	13	5	-4	5	-2	11	15	9	7	8	0	15	1	15	R-.	F
45	264.5	194.6	113.7	32.9	17.0	12	5	-4	4	-2	11	60	9	7	8	0	16	1	13	R-.	F
46	245.2	184.8	115.8	32.6	16.5	13	5	-4	5	-2	11	26	9	7	8	-1	16	1	14	R-.	F
47	276.6	207.4	131.5	31.7	17.7	13	5	-4	5	-2	11	42	9	7	8	0	16	1	19	R-.	F
48	245.8	214.6	132.1	31.1	17.5	12	6	-4	5	-2	11	34	9	7	8	-1	16	1	12	R-.	F
49	267.5	184.6	104.5	28.0	17.4	11	6	-4	6	-1	11	15	9	7	9	0	16	1	9	R-.	F
50	254.5	196.8	114.4	27.0	16.1	11	6	-4	6	-1	11	48	9	7	9	0	16	1	9	R-.	F
51	244.6	194.8	96.6	25.5	16.4	11	6	-4	5	-2	11	17	9	8	9	0	16	1	9	R-.	F
52	304.7	221.9	156.6	29.7	17.5	12	6	-4	5	-2	11	45	9	7	8	-1	16	1	11	R-.	F
53	317.2	251.3	194.4	35.9	17.5	12	6	-4	5	-2	11	26	9	7	9	0	16	1	11	R-.	F
54	356.3	277.3	198.5	43.2	17.7	12	5	-4	4	-3	11	27	9	7	9	0	16	1	10	R-.	F
55	313.7	247.8	191.1	49.6	17.7	13	5	-4	5	-2	11	47	9	7	9	-1	17	1	12	R-.	F S-R-
56	297.7	220.6	157.5	42.0	17.7	13	5	-4	6	-2	12	15	10	8	8	-1	17	1	11	R-.	F
57	291.2	221.8	156.5	39.2	17.3	12	5	-4	5	-2	12	57	10	8	9	0	17	1	10	R-.	F
58	338.7	281.5	215.3	64.1	17.7	13	6	-4	5	-2	11	41	9	7	9	0	17	1	11	R-.	F
59	268.2	268.5	183.0	72.6	21.5	14	7	-4	7	-1	12	14	16	8	9	-1	17	1	13	R-.	F

Figure 8. Example of One Hour of Automated Decision-Tree Program Output Beginning at 0100 GMT, 18 January 1979. FAA weather observations are plotted at extreme right

5. COMPARATIVE ANALYSIS OF OBSERVATIONS

The verification of the automated weather observations was accomplished through comparison with observations made by FAA control tower personnel at Otis AFB. The tower is located about 1.5 km east of the WTF. The FAA has responsibility for taking the official weather observations at Otis AFB and provided us copies for the 14-month period of the test.

Weather observers are required to make a "record" observation every hour.[18] The procedure is to start the observation within 15 min of its scheduled time and record the time the last element is observed. Since the AUTO observations were available every minute, predominant weather elements observed during the 15 min prior to the FAA record observations were determined and verified with the FAA observations.

It is worthwhile to restate that the portion of the aviation weather report we automated is composed of two elements, present weather and obstructions to vision. Consequently two verifications were performed. For the purpose of these verifications there are, generally speaking, five types of observations possible by the AUTO and the FAA:

(1) Obstruction of vision only (OV),
(2) Present weather only (PW),
(3) Obstruction of vision and present weather (OV and PW),
(4) No weather,
(5) No observation.

Thus, twenty-five possible combinations of FAA and AUTO observations may occur. The OV verification consisted of matching only the OV elements in both observations. For example, if both the FAA and AUTO observed rain and fog only, the OV element, fog, was considered. The PW elements (in this example, rain) were compared in the PW verification. If, on the other hand, the FAA observed rain and fog while the AUTO observed rain alone, this observation was counted as a verification for the PW program but a miss for the OV program. Therefore, in the following discussions of the verification of the two programs, although the same basic observation set was used, the numbers recorded in similar elements do not necessarily coincide.

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18. Federal Meteorological Handbook No. 1 (1972) Surface observations, A3, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

5.1 Obstructions to Vision Verification

The obstructions-to-vision observations were expanded to a 10 × 10 contingency table, Figure 9. The first seven columns and rows are labeled with the specific OV element. The meaning of each symbol is given in Table 1. The FAA observations are listed and summed in columnar form while the AUTO observations are listed and summed in rows. Thus the sums of the columns denote the frequency of the events observed by the FAA during the 14-month study while the row sums denote the AUTO frequency. Columns and rows labeled *PRES WX* refer to the number of hours when only a present weather element was observed. Those labeled NO WX denote those cases where no weather was observed. Finally, NO OB refers to the cases when no observation was available.

FAA OBSERVATION

AUTOMATED OBSERVATION	IF	BN BD	BS	H	FH	F	GF	PRES WX	NO WX	NO OB	
IF											
BN-BD											
BS											
H				98	94	76	1	2	42		313
FH				67	133	122		1	32		355
F			2	49	103	1539	5	187	178	12	2075
GF			2	10	25	33	51	3	64		188
PRES WX						4		25	8	1	38
NO WX			3	125	36	54	8	41	6576	18	6861
NO OB				11	6	114	4	8	251		394
			7	360	397	1942	69	267	7151	31	10224

Figure 9. Verification of Fourteen Months (March 1978 through April 1979) of Obstruction to Vision Observations Generated by the Automated Decision-Tree Program With FAA Weather Observations. Summation of columns represents frequency of event observed by FAA, summation of rows represents frequency observed by AUTO

In the discussions that follow, a particular element in the matrix will be referred to by coordinates defining each column and row. For example, FH/F will designate that element representing the number of hours of fog and haze (FH) observed by the FAA while the AUTO was specifying fog only (F).

The principal diagonal (H/H, F/F, and so on) shows that the AUTO was in agreement with the FAA in 82% of the observations when all diagonal elements are considered. If we consider the obstruction to vision alone, the AUTO was able to duplicate the FAA in 69% of the observations.

Other areas of particular interest are those which denote good but not perfect agreement. The elements FH/H, H/FH, F/FH and FH/F which agree in one obstruction only may be attributed to human causes because of the subjective nature of discriminating between fog and haze, whereas the AUTO system relies on the NEPH and FSM to discriminate between the two. If the NEPH and FSM measure EXCO's of equal magnitude which are greater than 3×10^{-4} m^{-1}, but less than 21×10^{-4} m^{-1}, the AUTO selects haze alone. If the NEPH measures an EXCO less than 3×10^{-4} m^{-1} while the FSM records one greater in magnitude, then AUTO selects fog alone. Finally, if the NEPH reading is less in magnitude than the FSM but still greater than the 3×10^{-4} m^{-1} threshold, then fog and haze are selected by AUTO. The same rules apply for the AUTO selections in the F/H and H/F categories. Perception of fog and haze, however, differs among individual observers, as indicated by changes in observations from fog to haze and vice versa from one work shift to the next. Many of the F/H cases began at night when human discrimination between fog and haze is particularly difficult. This could account for the greater number of observations in the F/H category than in the H/F. The remaining cases showed a tendency of the human observer to report haze in the higher ranges of visibility restriction and fog in the lower.

Only seven observations of blowing snow (BS/F, BS/GF, BS/NO WX) occurred during the study and AUTO failed to correctly specify them. Instead, AUTO observed light snow and fog (S-F) in two cases and in two other cases light snow and ground fog (S-GF) because the wind gust determination was functioning improperly. In the three remaining cases AUTO observed no weather because it was reporting visibilities of seven to eight miles which require no obstruction to vision determination, while the FAA reported visibilities of less than seven miles which do require obstruction determination.

Combining individual elements of visibility restriction into broader groups was accomplished, Figure 10, using rationale analogous to that used in the preceding fog-haze discussion, the purpose being the highlighting of the strengths and weaknesses of the AUTO program.

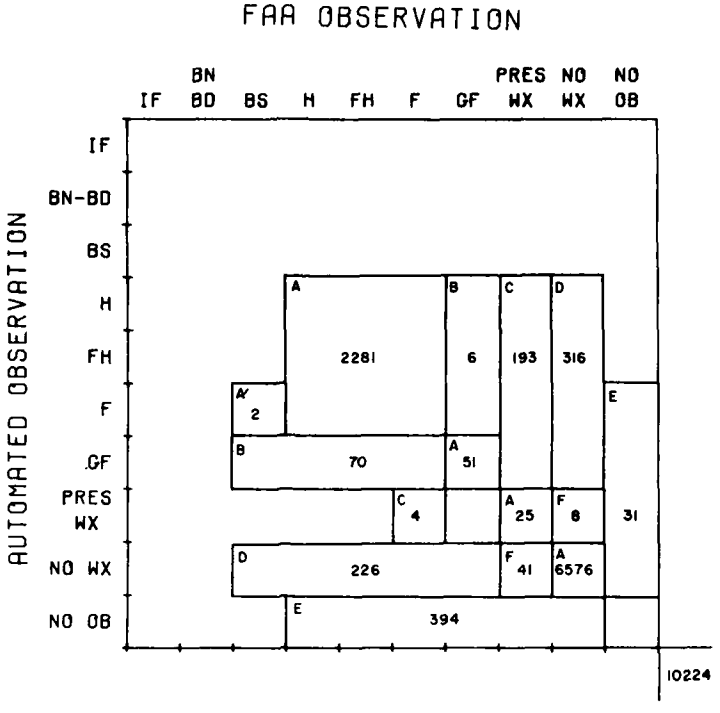

Figure 10. Simplification of Figure 9 Through Categorization

Categories labeled A and A' were discussed in the preceding paragraph. Category B has two sections. The first specifies the number of observations of ground fog (GF) by the FAA while the AUTO reported fog or haze; the second specifies the opposite set of conditions. There is a large disparity in the number of observations between the sections. The numbers here and in Figure 9 indicate that the AUTO observes ground fog much more frequently than it should. Since the criterion for selection of ground fog is based on the percentage variation of visibility with height, it is apparent that this criterion should be adjusted.

The first section labeled C contains the number of observations (193) that the FAA reported a present weather element (PRES WX) only while the AUTO reported an obstruction to vision (OV) or a combination of OV and PW. In about 140 of these cases the FAA observed either snow or rain alone while the AUTO observed snow and fog or rain and fog. Thus, following our verification scheme, they were considered as failures in the OV program, but were considered as verifications in the PW program. These observational differences can be attributed to two possible causes, a characteristic of the AUTO program to search for an obstruction to vision

in addition to a present weather element when the visibility is less than seven miles, and a bias on the part of the FAA observer to allow a present weather element alone to account for the total restriction to visibility.

The remaining 53 observations consisted of FAA reports of snow or rain and of AUTO reports of fog, ground fog, haze, or fog and haze. These are entirely attributable to the AUTO rain gage. In these cases, either no tip occurred or it was delayed beyond the hourly observation time because precipitation was very light. In all these cases, however, the AUTO, noted a decrease in visibility below seven miles, and sought a cause in the OV portion of the decision tree.

In the second section of C, the AUTO observed present weather only four times while the FAA was observing fog. In these cases, the AUTO did observe a tip of the rain gage but because of time or distance separation the FAA did not observe precipitation. The AUTO also determined visibility to be greater than seven miles and, therefore, indicated no obstructions, while the FAA reported visibilities of five and six miles and observed fog as the obstruction.

Categories D list the number of times when the FAA reported no weather while the AUTO reported an obstruction and, conversely, the number of times when the AUTO reported no weather while the FAA recorded some restriction to visibility. The number of times this occurred is similar in both categories. Closer examination of the individual cases revealed two causes for these discrepancies. This first is based on the rule which requires a restriction to visibility to be reported when the visibility is less than seven miles. In about 50% of the observations the AUTO and FAA observed visibilities on opposite sides of this value. The second cause, which accounted for the remainder of the discrepancies, was due to the distance between the two observation points. This space separation manifested itself in time differences of onsets and clearings of fog and ground fog.

The fifth category, E, documents the number of times either system failed to make an observation during the 14-month period. The AUTO failed to function in 394 cases. This 4% down-time of the AUTO was due to malfunctions of the data recording system. The FAA, on the other hand, was unable to file observations for 31 hr because of tower-heating-system failure during an extremely cold period.

The final category, F, which relates the number of times one system reports present weather while the other reports no weather and conversely, is really a partial report on the present weather system discussed in detail in Section 5.2. The higher frequency, 41, of PRES WX/NO WX was due to two causes: first, the distance between observation points which resulted in different beginning or ending times of precipitation; and second, light precipitation (either snow, drizzle, or rain) to which the rain gage was inherently slow in reacting, coupled with visibilities greater than seven miles. The eight occurrences in NO WX/PRES WX were due to station separation.

5.2 Present Weather Verification

The present weather verification, Figure 11, consists of the FAA and AUTO hourly observations for the 14-month period of study arranged in a 9 × 9 matrix. The first five rows and columns of the matrix are the weather elements selected from Table 1. The remaining rows and columns allow for the possibility of obstruction to visibility only (OSTN to VISN), no obstructions or weather (No WX) and no observations available (No OB).

FAA OBSERVATION

AUTOMATED OBSERVATION	ZR	ZL	S	R	L	OSTN TO VISN	NO WX	NO OB	
ZR				5		1			6
ZL			6						6
S	1		98	2	2		5	1	109
R			2	503	21	31	27	6	590
L			1	109	26	26	17	3	182
OSTN TO VISN			31	131	69	1567	275	3	2076
NO WX			7	34	9	217	6576	18	6861
NO OB				52	20	71	251		394
	1		145	836	147	1913	7151	31	10224

Figure 11. Verification of Fourteen Months (March 1978 through April 1979) of Present Weather Observations Generated by the Automated Decision-Tree Program (AUTO) With FAA Weather Observations. Summation of columns represents frequency of events observed by FAA, summation of rows represents frequency observed by AUTO

The principal diagonal gives a remarkably high agreement of 86%. Major contributions, however, to this agreement are from the two categories involving obstructions to vision and no weather. This simply reflects the low frequency of present weather events at Otis AFB during the 14-month period. For example, the

FAA frequency of weather events can be obtained by summing the columns titled ZR, S, R, and L. They total 1129 and indicate that weather occurred during only 11% of the 14-month period of observations. Considering those events alone, the AUTO correctly identified 627, or 56%, of them. Most of the inconsistency in PW determination lies in the drizzle category for which only a 20% agreement was reached. Snow, on the other hand, yielded a 68% agreement while rain was at 64%.

Before combining the separate elements for general discussion, reference to the R/L element reveals that AUTO observed drizzle (L) frequently when the FAA observed rain (R). The drizzle-rain discrimination in AUTO was based on empirical evidence that indicated similar responses by the FSM and the TRANS in drizzle and dissimilar responses in rain. Thus, this discrepancy can be due to one of two factors, an error in the AUTO relationship just described or a bias on the part of the FAA observer, in which certain drizzle events were improperly specified as rain events.

On the other hand, reference to the total FAA drizzle observations (147) and the L/L and L/OSTN TO VISN elements shows that the tipping bucket (0.005 in.) rain gage was long delayed or did not respond at all in many of the drizzle occurrences. In spite of the latter discrepancy, the net result was a greater frequency of drizzle observations by AUTO (182) than by the FAA (147).

In order to facilitate further discussion of the contingency matrix, the individual elements were consolidated into similar but fewer categories, see Figure 12. The categories contain groups which represent frozen precipitation, liquid precipitation, obstructions to vision, no weather, and no observation. If these categories alone were acceptable as an observing system, then AUTO would have a verification of 87%.

Category B represents the cases when frozen precipitation was observed by the FAA and not by AUTO and vice versa. In the first case the three AUTO observations of liquid precipitation were due to a malfunctioning VIDE and the resultant failure of the VIDE-FSM relationships to correctly discriminate snow. In view of the high success rate (S/S) shown in Figure 11 (98 out of a possible 145 snow observations), this represents a small error. In the second case of Category B, the nine observations were divided almost equally between incorrectly observed snow and freezing rain. Evidently, refinement is required on the frozen precipitation algorithm since AUTO observed more than actually occurred. Spatial separation of observing points should not be too important in this category, but the height of the observation points may be. At Otis AFB the FAA observers are located in the control tower at a height of 96 ft while the AUTO surface instruments are located about 6 ft above the ground. The C category contains two elements, the first of which (S, R, L/OSTN TO VISN) consists of FAA observations of PW and PW and OV, and AUTO observations of obstructions to vision (OV) only. Examination

of the records showed that AUTO failed to observe a present weather element when the FAA did for a variety of reasons. The first of these is due to the spatial separation of the stations. Precipitation started and ended at significantly different times on many occasions. The next reason involves the rain gage used by AUTO. Precipitation might start at the same time at both stations but the tipping-bucket rain gage would have a time lag in reporting this precipitation until the first 0.005 in. of rain was collected. The third reason, also due to the rain gage, would result in no precipitation being reported if the total rainfall was less than 0.005 inches. AUTO did, however, record an obstruction to vision because the visibility observed was less than seven miles.

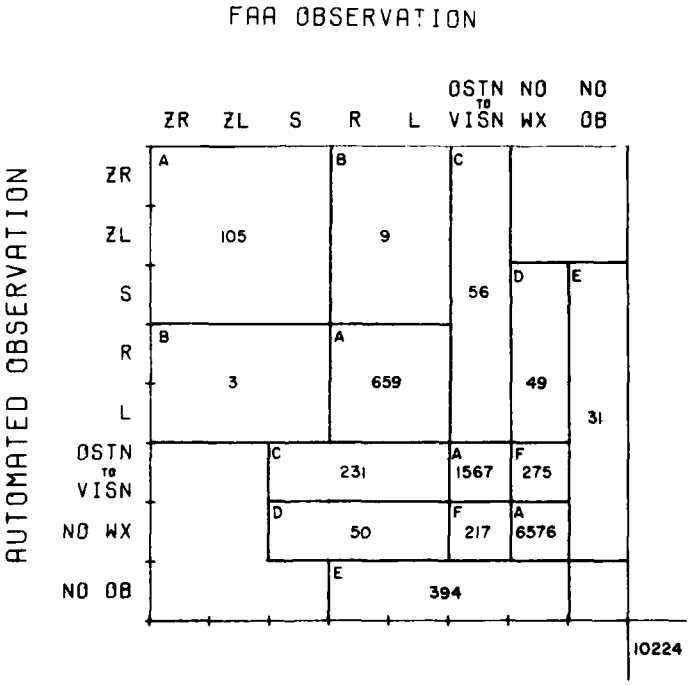

Figure 12. Simplification of Figure 11 Through Categorization

In the second C category, OSTN TO VISN/ZR, ..., and L, only 58 cases occurred when the FAA observed an OV while the AUTO observed a PW. Station separation also plays a major role here with a secondary contribution from the

algorithm, which terminates precipitation quickly following the tip if visibility improves above seven miles. If the visibility remains low, however, AUTO will continue to indicate precipitation for a 60-min period.

The observations in categories D and F in Figure 12 are identical to those found in the same categories of Figure 10. The sums of observations in both figures are equal, although the individual terms differ because of the verification procedures dealing with combined observations of weather and obstruction to vision. The discrepancies in the D category, Figure 12, can be ascribed to various causes. The inability of the tipping-bucket rain gage to respond rapidly to light precipitation is a primary factor. Another factor which became apparent upon reexamination of the data was station separation which resulted in different beginning and ending times of precipitation. A final factor, previously noted, was the AUTO algorithm which attempted to determine the ending time of precipitation. The reasons for the differences in Category F are the same as cited in the previous section, that is, station separation and the disagreement between FAA and AUTO visibility observations near the seven-mile range. The E category in Figure 12 is exactly the same as in Figure 10 and represents the non-operating periods for both observational systems, FAA and AUTO, during the 14-month study.

6. SUMMARY AND CONCLUSIONS

A study was performed to determine the feasibility of objectively and automatically determining two key components of an aviation weather observation; obstructions to vision and present weather. The automatic system utilized was the AFGL Weather Test Facility located at Otis AFB, Massachusetts. Within its framework a MAWS type automated weather system was selected to consist of an instrumented tower and a surface complex of sensors. The objective method consisted of a decision-tree program based on several uniquely different responses by these weather sensors to the same weather phenomena, and on discrimination techniques using tower and surface instruments.

The characteristics and techniques were demonstrated through selected hourly periods of observations taken at 1-min frequencies by the computerized decision-tree programs called AUTO. The ability of the automatic system to monitor rapidly changing weather events was clearly shown in the cases of rain intensity. In fact, it far surpasses the human observer in this ability. Sequences were also presented which typified the ability of AUTO to select haze, fog and haze, ground fog, and snow.

Fourteen months of hourly weather observations taken by the FAA and AUTO were compared to determine the effectiveness of the automatic system. The results show that the AUTO duplicated the FAA observations of obstructions to vision and present weather in 82% and 86% of the cases.

Major areas of agreement in the test involving obstruction to vision were in the discrimination of fog, haze, no obstruction, and combinations of fog and haze. Ground fog was correctly identified by AUTO in 75% of the FAA-observed cases. AUTO, however, generated considerably more observations of ground fog than did the FAA. While the ground fog algorithm used in AUTO may need to be refined somewhat, this difference may also be due to height differences between the FAA and AUTO observation points.

The areas of major disagreement in the test involving obstructions to vision can be attributed mainly to two factors. The first factor, as pointed out in Section 5.1, is based on the regulation which requires that an obstruction be reported when the prevailing visibility is less than seven miles. For example, if the FAA observer were to report a visibility of six miles, he would be required to report an obstruction to vision. However, if the AUTO observation were seven miles, in very close agreement with the FAA observation, no obstruction would be reported. Thus, the test to compare the AUTO obstruction to visibility observation with that of the FAA also became a test of how well the AUTO determined prevailing visibility. The second cause of discrepancies was the distance between the FAA and AUTO observation points. This distance was most significant in accounting for the differences in time of onset and clearance of fog.

Major areas of agreement in the present weather test were found in the discrimination of snow and rain. The VIDE-FSM algorithm for snow determination worked extremely well, and both instruments performed reliably and accurately. The algorithm for rain determination was also very reliable.

The major problem areas for the weather determination program were related to short sampling period and instrumental problems. The fourteen months of record yielded a very low frequency of most weather events and the almost total lack of freezing rain and drizzle. The instrumental problem in the weather program involved the key instrument, a tipping-bucket rain gage. Even though the instrument was designed to record very light precipitation amounts, 0.005 in., its inability to determine precisely the beginning and ending of precipitation caused many observational discrepancies. A contributing factor to these discrepancies was the separation between observation points.

In conclusion, it has been demonstrated that data from a selected array of automated weather sensors can be used in conjunction with a decision-tree computer program to identify a wide variety of weather and visibility restriction elements. Thus, the acquisition of real weather for an aviation weather observation, a duty presently performed by the human observer, is obtainable through the addition of a small group of instruments to the Modular Automated Weather System. The inclusion of an objective method of this type in a software system designed for the Automated Weather Distribution System (AWDS) should be given serious consideration.

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